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# Security Seal Handbook

David L. Poli

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Sandia National Laboratories
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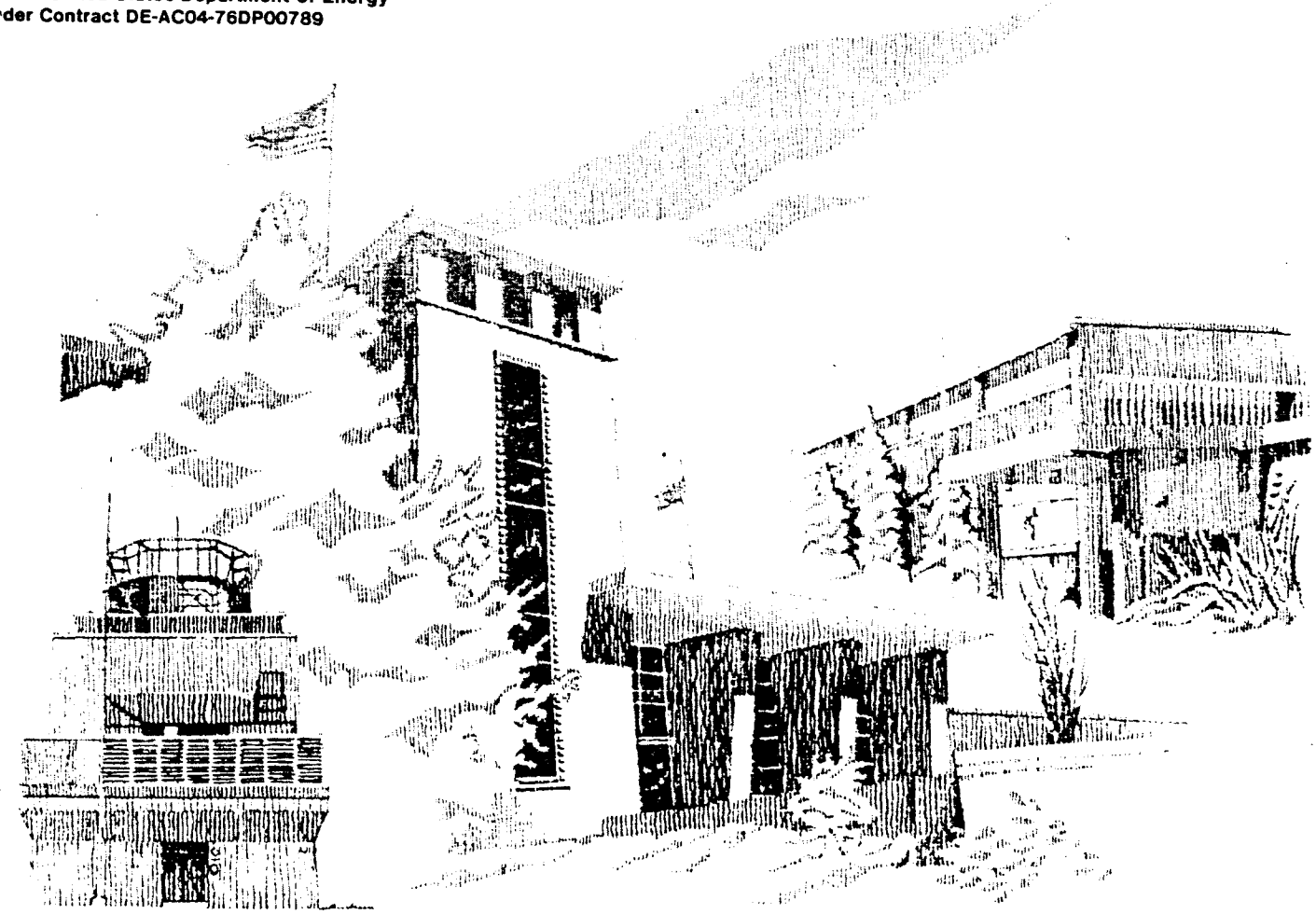

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# SECURITY SEAL HANDBOOK

**David L. Poli**

Nuclear Security Systems 1700
Sandia Laboratories
Albuquerque, NM 87185

**ABSTRACT**

This handbook describes the security seal system philosophy, provides descriptions, evaluation information, installation guidelines, and verification instructions for available seals, and supplies information on the development of new seals.

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# ACKNOWLEDGMENTS

The compilation of this handbook required the cooperation of many organizations both outside and within Sandia Laboratories. Acknowledgement of all those individuals who participated in this study is not possible; however, there are some individuals and groups whose special efforts were fundamental to the results presented in this handbook.

The reports provided by Brookhaven National Laboratory's Technical Support Organization and the U.S. Army Intelligence Material Development and Support Office of the Electronic Warfare Laboratory contained information on a number of the seals discussed in this handbook.

Robert A. Lederer, Sandia Laboratories, who served as consultant, was instrumental in developing much of the tamper-resistance information contained in this handbook.

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ILLUSTRATIONS



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# 1. INTRODUCTION

## PURPOSE OF HANDBOOK

This handbook was prepared as part of the Sandia Laboratories Fixed Facility Physical Protection program under the auspices of the Department of Energy, Office of Safeguards and Security (DOE/OSS). The purposes of the handbook are

1. To state the general seal system philosophy,
2. To provide descriptions, evaluation information, installation guidelines, and verification instructions for commercial seals and special seals used by DOE, and
3. To provide information concerning the development of new seals.

This handbook does not attempt to specify seal systems for a wide spectrum of facility applications. Rather, the intent is to present the reader with information so that he may select the seal or seals which best meet his specific needs.

## DISCUSSION

Information obtained after September 1978 could not be included in this handbook. However, new information will be added to the handbook as it becomes available.

Specifications and regulations concerning security seals are already in existence. Pertinent documentation on seal requirements includes

1. DOE Order 5630.1 (draft), "Control and Accountability of Nuclear Materials,"[1]
2. Regulatory Guide 5.10, *Pressure Sensitive Seals*,[2]
3. Regulatory Guide 5.15, *Security Seals for Special Nuclear Material*,[3] and
4. Military Specification, MIL-S-23769B, Seals.[4]

The information contained in this handbook is not intended to replace any of the previous requirements and may complement them by serving as a guide.

The following paragraphs describe the philosophy which was adhered to during the preparation of this handbook. In many instances, the philosophy reflects the contents of References 3 and 5.

### Security Seals

Security seals can be defined by the following characteristics:

1. A security seal is a device used to detect tampering.
2. Frangibility is a common property of most seals; they are not intended as a deterrent or barrier to an adversary willing to use force.
3. Inspection is required to determine if seals have been tampered with.
4. Seals are nonreversible in the sense that once they are broken, they are difficult to reassemble without leaving signs of the tampering.
5. Seals are identifiable, i.e., they may be distinguished by the addition of unique identification characteristics such as sequential serial numbers, scratches, or other random marks.

### Function of a Seal System

Seals are devices which are applied at convenient locations to detect tampering and unauthorized entry by the use of periodic inspections. Seal systems consist of the seals themselves and the sets of procedures, techniques, and devices used for

1. Procurement, storage, and fingerprinting of the seals,
2. Selection of the point of application,
3. Application, removal, and identification of the seals, and
4. Inspection to determine whether entry or tampering has occurred.

The objective of utilizing a seal system is to provide a level of assurance that no tampering or entry has occurred during the period that the seal was applied or the interval between inspections. If the scheme used by a potential adversary requires that tampering with the sealed object be undetectable, the seal will present an added obstacle which will force the adversary to undertake extra activities.

The chance that the adversary will make a mistake and be detected is therefore increased. A weakly motivated adversary may be deterred from action simply as a result of the psychological effect produced by the physical presence of security measures such as the security seal.

## Limitations of Sealing Systems

The limitations of present sealing systems are

1. The entire containment system must be tamper-resistant to the same degree as the seal, e.g., why seal a door if the hinge pins can be easily removed?
2. All commercial seals may be substituted by a similar seal which can be procured from the manufacturer and marked with the same identifier (serial number, etc.). The removed seal could then be replaced with the duplicate after the adversary's goal is completed.
3. A seal system may be of little value if the supply of spare seals is not properly protected. If proper protection is not provided, the adversary could easily obtain a new seal to replace any seal broken during an entry attempt.
4. Any method of fingerprinting (the application of unique identification characteristics) can probably be defeated if the record of seal fingerprints is accessible to potential adversaries. In this case, the adversary could substitute fingerprint records of the counterfeit seals used.
5. Commercial seals are not manufactured with any fingerprint (except a serial number). All available information indicates that the Type E (cup/wire) seal is the only seal that has been modified to include a unique fingerprint.
6. All known commercial seals may be defeated. A number of methods may be used: reversal of the manufacturing processes used to produce the seal, forcible entry with subsequent repair of damage, and careful manipulation.
7. If the verification inspection methods are not thorough enough to find evidence of tampering, the seal system will lose effectiveness.
8. A sealing system can also fail if the ways in which the seals are applied makes them vulnerable to accidental destruction. In such instances, a history of accidental destruction might be used to conceal willful attacks.

Sealing systems, like all other means of detection, offer no absolute guarantees. For each seal system, the probability of detection decreases as the cost or magnitude of effort the adversary is willing to expend toward defeating the system increases. New seal developments are presented in Section 4 which may eliminate some of the limitations.

# 2. SUMMARY

In the preparation of Section 3 of this handbook, all of the seals shown in Figures 1 and 2 were considered. These seals are representative of all known commercially manufactured seals as well as special seals used within DOE facilities. For the purposes of this handbook, all the seals are assigned to a category which best describes the seal construction. Each type of seal is described in detail in Section 3.

Table I provides relative price information and an index which relates each specific seal to the appropriate figure in which it is shown. Table II provides the addresses for all of the seal manufacturers listed in Table I. Table III provides tamper-resistance data on the seals presented in Section 3.

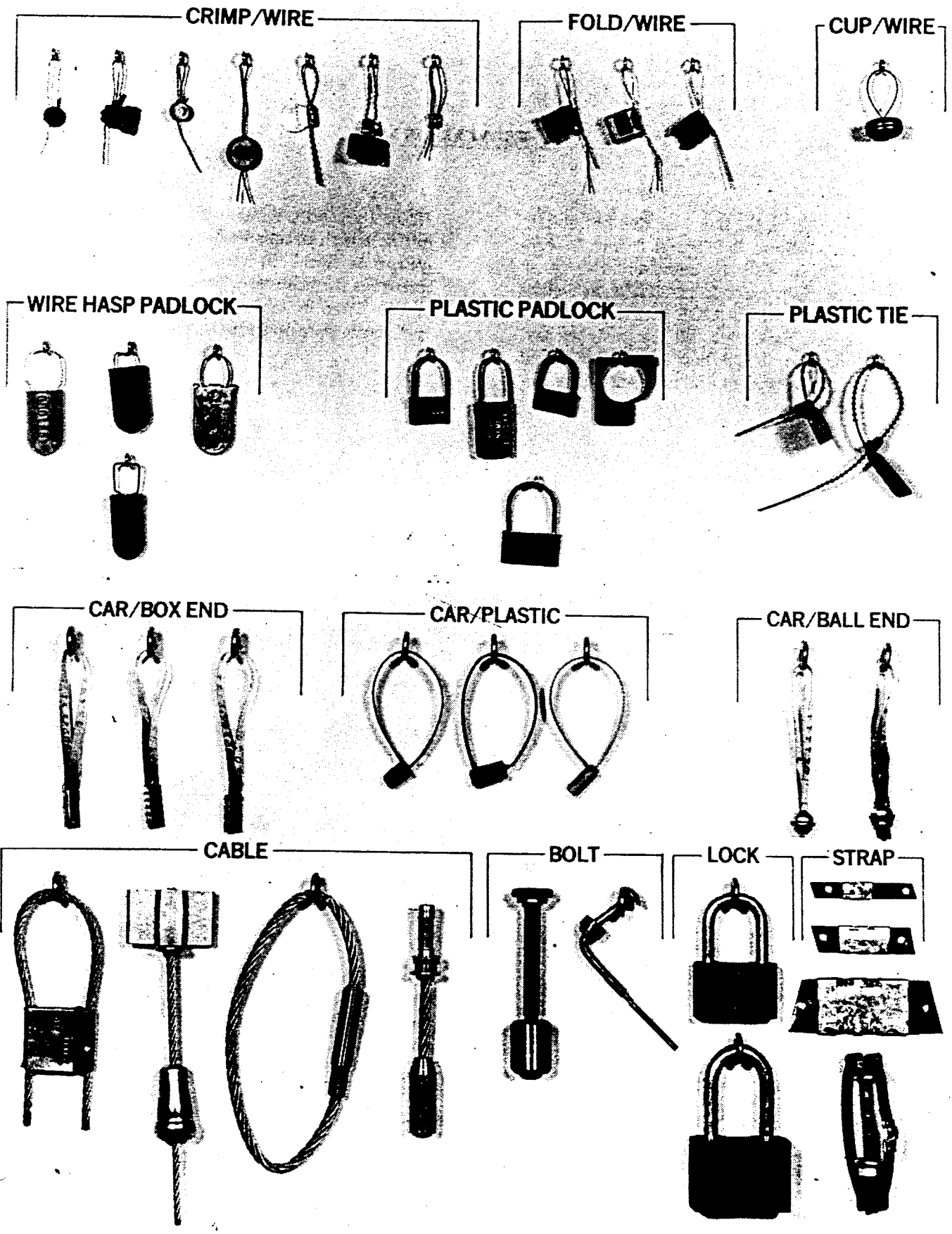


Figure 1. Commercial Seals

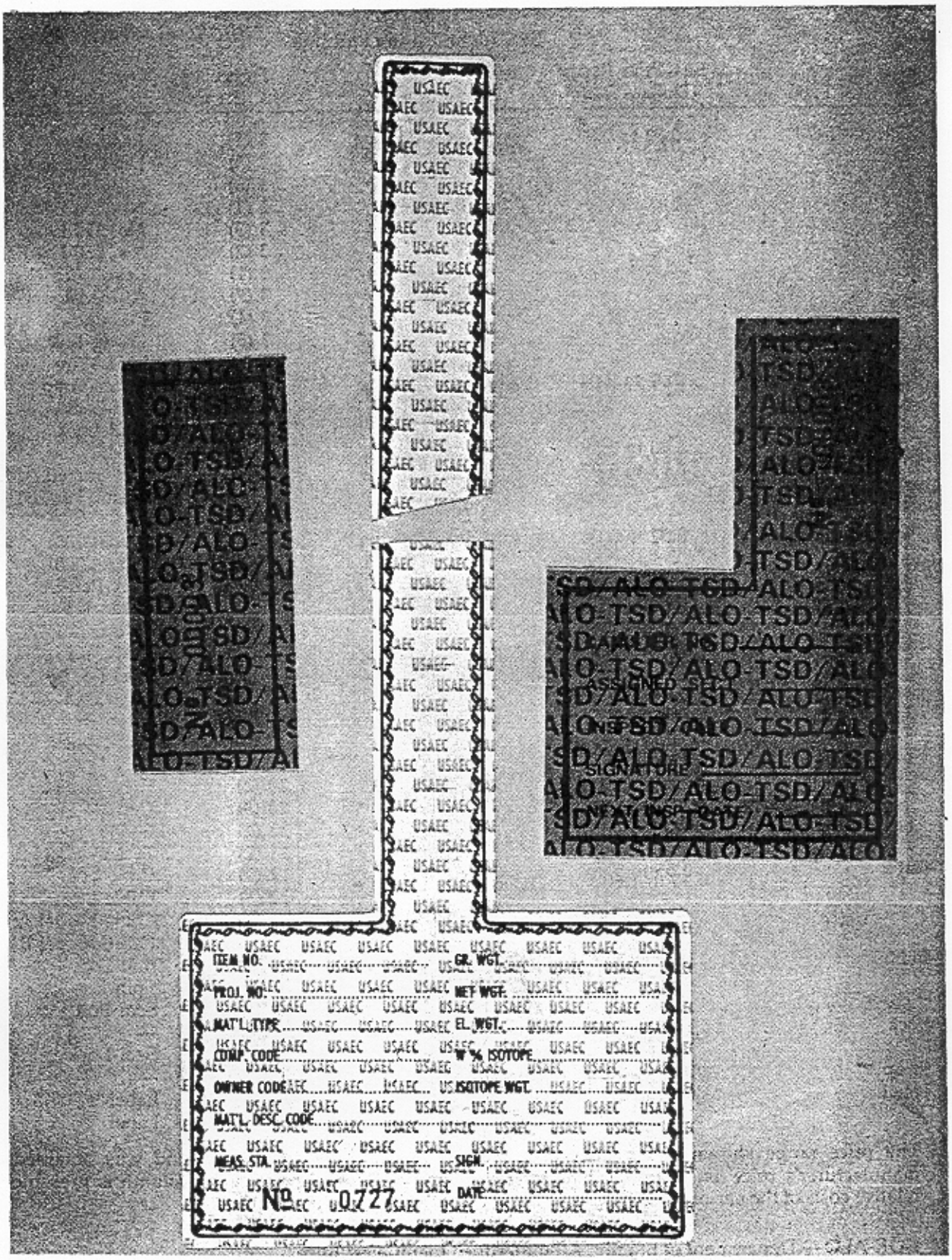


Figure 2. Label Seals

TABLE I

Seal Identification and Index

| Seal Type | Seal Price Range (Dollars/Seal)[a] | Manufacturer | Figure No. (Item) | Seal Name |
|---|---|---|---|---|
| Crimp/Wire | 0.02 to 0.07 | American Casting | 3 (1) | Lead/Wire |
| | | | 3 (3) | Lead Metal Back |
| | | | 3 (6) | Aluminum |
| | | Brooks | 3 (1) | No. 134 Lead/Wire |
| | | | 3 (3) | No. 170 Lead Metal Back |
| | | | 3 (2) | No. 160 Lead Number |
| | | Gibson | 3 (1) | Lead/Wire |
| | | Stoffel | 3 (7) | Alu-Cast |
| | | | 3 (4) | Prestige |
| | | | 3 (5) | Prong-Lok |
| | | United | 3 (1) | Lead/Wire |
| Fold/Wire | 0.02 to 0.04 | American Casting | 4 (1) | Amer-Snap |
| | | Stoffel | 4 (2) | Self-Lock |
| | | | 4 (3) | Fold-Lock |
| Cup/Wire | 0.40 to 0.59 | American Casting | 5 | E-Seal |
| Wire Hasp Padlock | 0.03 to 0.07 | American Casting | 6 (3) | Galvanized Padlock |
| | | Brooks | 6 (1, 2) | Plastic Padlock |
| | | Dickey | 6 (4) | — |
| Plastic Padlock | 0.02 to 0.04 | American Casting | 7 (1) | Model 1001 |
| | | | 7 (2) | Model 2001 |
| | | Brooks | 7 (5) | Poly Pad-Loc |
| | | Stoffel | 7 (3) | Padlock Seal |
| | | | 7 (4) | Handi-Lok |
| Plastic Tie | 0.05 to 0.06 | American Casting | 8 (1) | Pull-Up Model 3001 |
| | | Brooks | 8 (2) | Pull-Tite No. 661 |
| Car/Box End | 0.01 to 0.02 | Brooks | 9 (1) | Sure Lock |
| | | Dickey | 9 (2) | Premier |
| | | Security | 9 (3) | Sonic-Lock |
| Car/Plastic | 0.03 to 0.07 | Brooks | 10 (1) | Poly-Loc |
| | | Security | 10 (2) | Poly-Tek-Tiv |
| | | Stoffel | 10 (3) | Canada |
| Car/Ball End | 0.03 to 0.04 | Dickey | 11 (1) | Globe |
| | | Tyden | 11 (2) | Tyden |
| Cable | 0.55 to 1.60 | Brammall | 12 (2) | Cone Loc |
| | | | 12 (1) | Cable Loc |
| | | Brooks | 12 (3) | Cable Model A |
| | | | 12 (4) | Cable Model B |
| Bolt | 0.20 to 1.00 | Brammall | 13 (2) | Bolt Loc |
| | | | 13 (2) | Spin Loc |
| | | Kwikset | 13 (1) | Seal-Bolt |
| Lock | 1.35 to 3.75 | Aardee | 14 (2) | — |
| | | Kwikset | 14 (1) | Seal-Lock |
| Strap | 0.01 to 0.03 | Signode/DOE-ALO[b] | 15 | — |
| Label | 0.40 to 1.50 | Advertape | 16 | Label |
| | | Designer Decal | 16 | Label |

[a] The price range shown is for seals procured in quantities of 1,000 each and was obtained from the manufacturer's price list or from billing for recent purchases. The price range column is presented to show relative costs of the various seal types and is not meant to be used for ordering.

[b] DOE-ALO — Department of Energy, Albuquerque Operations Office.

TABLE II

Seal Manufacturers' Addresses

Aardee Spring & Lock Co., Ltd.
P.O. Box 39
Hudson, Massachusetts 01749

Advertape Inc.
1189 Montauk Hwy.
East Patchogue, New York 11772

American Casting & Mfg. Corp.
51 Commercial St.
Plainview, New York 11803

Brammall, Inc.
P.O. Box 208-TR
Angola, Indiana 46703

E. J. Brooks Co., Inc.
175 N. 13th St.
Newark, New Jersey 07107

Designer Decal Inc.
131 North Pittsburgh
Spokane, Washington 99202

Dickey Mfg. Co.
1317 E. Main St.
St. Charles, Illinois 60174

A. C. Gibson Co., Inc.
877 Englewood Ave.
P.O. Box 89
Buffalo, New York 14205

Kwikset Powdered Metal Products
Division Emhart Corp.
711 E. South St.
Anaheim, California 92803

Security Seal Co., Inc.
30-32 Intersection St.
Hempstead, New York 11551

Stoffel Seals Corp.
68 Main St.
Tuckahoe, New York 10707

Tyden Seal Company
210 N. Industrial Park Rd.
Hastings, Michigan 49058

United Seal Co.
2002 Fairwood Ave.
Columbus, Ohio 43207

TABLE III

Tamper-Resistance Tabulation

| Seal Type | Figure No. (Item) | Original Parts | Simple Tools | Min. Defeat Time | Tamper Detection Inspection Level ① | ② | ③ | ④ |
|---|---|---|---|---|---|---|---|---|
| Crimp/Wire | 3(1) | Yes | Yes | 5 min | No | No | No | Yes |
| | 3(2) | Yes | Yes | 5 min | No | No | No | Yes |
| | 3(3) | Yes | Yes | 5 min | No | No | Yes | Yes |
| | 3(4) | Yes | Yes | 5 min | No | No | Yes | Yes |
| | 3(5) | Yes | Yes | 2 min | No | No | No | No |
| | 3(6) | Yes | Yes | 30 sec | No | No | No | No |
| | 3(7) | Yes | Yes | 5 min | No | No | Yes | Yes |
| Fold/Wire | 4(1) | Yes | Yes | 2 min | No | No | No | Yes |
| | 4(2) | Yes | Yes | 2 min | No | No | No | Yes |
| | 4(3) | Yes | Yes | 2 min | No | No | No | Yes |
| Cup/Wire | 5 | No | No | 10 min | No | No | No | Yes |
| Wire Hasp Padlock | 6(1) | Yes | Yes | 15 sec | No | No | No | No |
| | 6(2) | Yes | Yes | 15 sec | No | No | No | No |
| | 6(3) | Yes | Yes | 5 min | No | No | No | Yes |
| | 6(4) | Yes | Yes | 15 sec | No | No | No | No |
| Plastic Padlock | 7(1) | Yes | Yes | 30 sec | No | No | No | Yes |
| | 7(2) | Yes | Yes | 2 min | No | No | Yes | Yes |
| | 7(3) | Yes | Yes | 2 min | No | No | Yes | Yes |
| | 7(4) | Yes | Yes | 2 min | No | No | Yes | Yes |
| | 7(5) | Yes | Yes | 2 min | No | No | Yes | Yes |
| Plastic Tie | 8(1) | Yes | Yes | 1 min | No | No | No | Yes |
| | 8(2) | Yes | Yes | 1 min | No | No | No | Yes |
| Car/Box End | 9(1) | Yes | Yes | 30 sec | No | No | No | No |
| | 9(2) | Yes | Yes | 30 sec | No | No | No | No |
| | 9(3) | Yes | Yes | 30 sec | No | No | No | No |
| Car/Plastic | 10(1) | Yes | Yes | 3 min | No | No | Yes | Yes |
| | 10(2) | Yes | Yes | 15 sec | No | No | No | Yes |
| | 10(3) | Yes | Yes | 3 min | No | No | Yes | Yes |
| Car/Ball End | 11(1) | Yes | No | *5 min | No | No | No | Yes |
| | 11(2) | Yes | No | *5 min | No | No | No | Yes |
| Cable | 12(1) | Yes | Yes | 30 sec | No | No | No | No |
| | 12(2) | Yes | Yes | 10 min | No | No | No | Yes |
| | 12(3) | Yes | Yes | 2 min | No | No | No | Yes |
| | 12(4) | Yes | Yes | 30 sec | No | No | No | Yes |
| Bolt | 13(1) | Yes | Yes | 30 sec | No | No | No | Yes |
| | 13(2) | Yes | Yes | 5 min | No | No | No | Yes |
| Lock | 14(1) | Yes | Yes | 2 min | No | No | No | Yes |
| | 14(2) | No | Yes | *60 min | No | No | No | Yes |
| Strap | 15 | No | No | 5 min | No | No | No | Yes |
| Label | 16 | (No Known Defeat) | | | | | | |

*Estimated minimum defeat times.

TABLE III (continued)

Table III is a tabulation of the seal tamper-resistance summaries presented in Section 3. The guidelines and explanations which apply to Table III are

1. All the seals, except the strap and label seals, are commercial products and are subject to change by the manufacturer, which may alter the results shown in the tabulation .
2. Substitution of a duplicate seal for an installed seal is not considered in the tabulation since all seals may be compromised by substitution, and, in many cases, this may be the most feasible method of surreptitiously defeating a seal.
3. The following list identifies the different columns appearing in Table III and explains their significance:
   a. Seal Type — In this first column, the different types of seals, as presented in Figures 1 and 2, are listed.
   b. Figure No. (Item) — In this column, the figure and item numbers used in Section 3 to refer to specific seals are listed.
   c. Original Parts — A "yes" in this column means the seal can be opened and reclosed by the use of only the original parts. A "no" means some, but not all, parts were substituted in the seal defeat.
   d. Simple Tools — A "yes" in this column means a defeat can be accomplished by the use of commercially available hand tools and/or simple instruments such as shims, wire, etc. A "no" means defeat required the use of special tools such as dies, presses, etc., but could be accomplished in the field.
   e. Minimum Defeat Time — The times listed in this column are based on the results of actual defeat for the specific seal or, in some cases (indicated by an asterisk), are estimates based on similar seals or defeat tasks.
   f. Tamper Detection Inspection Levels (four columns) — This category is subdivided into four levels of inspection:
      (1) Presence of seal inspection,
      (2) Routine inspection,
      (3) Careful examination of the installed seal, and
      (4) Post-mortem examination.

      A "no" means the evidence of defeat will most likely *escape detection*. A "yes" means the evidence of defeat will most likely *be detected*.

# 3. EVALUATIONS, INSTALLATION GUIDELINES, AND VERIFICATION INSPECTION

This section is divided into several subsections, each of which addresses a different type of seal. Each subsection follows a standard format and includes

1. A photograph of the seal,
2. A seal description,
3. A tamper-resistance summary,
4. Special installation guidelines, and
5. A description of verification inspection methods.

A description of the information contained in these subsections is provided in the following paragraphs.

## SEAL DESCRIPTION

The seal description is a short narrative which supplements the seal photograph and provides pertinent information concerning the design features of the seal. Since it is possible to have the manufacturer provide a sequential serial number on the seal as a unique identifier, information regarding identifiers is also contained in the description.

## TAMPER-RESISTANCE SUMMARY

The tamper-resistance summary presents conclusions based on the evaluations contained in Reference 6. The term *compromised,* as it is used in this summary, is defined to be *any action by which a seal can be opened and reclosed, using the original parts, with commercially available hand tools or very simple instruments,* e.g., shims or wire. *Evidence of defeat* of the seal *will most likely escape detection* except through the use of *post-mortem examination.* Exceptions to this definition are noted, where applicable, in the summary.

All of the seals, except the strap and label seals, are commercial products and are subject to change by the manufacturer, which may alter the tamper-resistance data presented.

The summary does not consider substitution of a duplicate seal for the installed seal as a compromise even though all the seals may be compromised by substitution and, in many cases, this may be the most feasible method to use for compromise of the seal system.

The time estimates presented in the tamper-resistance summary are based on the results of actual defeat of the specific seal or, in some cases, are estimates based on the results of similar defeat tasks. Seal tampering, in most cases, is not a precise mechanical procedure but requires practice in the skills of touch, sound, and sight, correct application of forces, etc. Only the times believed to be indicative of the minimum times that would be experienced by an adversary proficient in performing the defeat have been used in the tamper-resistance summary.

## SPECIAL INSTALLATION GUIDELINES

The special installation guidelines contain information on seal installation that is generally not provided in the manufacturer's instructions. The information given in the tamper-resistance summary and the verification inspection section is based on the assumption that these special precautions have been adhered to.

## VERIFICATION INSPECTION

There are various degrees of seal verification that may be used, depending upon the degree of confidence required. In addition, the degree of confidence achieved will increase with each succeeding verification inspection. The different types of inspections which could be used include

1. Presence of seal inspection,
2. Routine inspection,
3. Careful examination of the installed seal, and
4. Post-mortem examination.

Currently, the presence of seal and routine inspections are commonly used as seal verification methods. Observing a seal from some distance satisfies the presence of seal inspection, while pulling on the seal, checking its serial number, and performing a quick visual examination, satisfies the routine inspection. However, while these two methods of verification may be appropriate for some seal systems (such as sealing low-value materials), it is necessary to realize that they offer the lowest degree of confidence since crude methods of seal defeat (such as cutting and gluing) may be used with a high probability that the defeat will escape detection. Since these are general verification methods which would be appropriate for all seal types, they have been purposely omitted from the verification inspections described in this section.

The verification inspections contained in this section address only the careful examination of installed seals and the post-mortem examination. Careful examination of the installed seal provides instructions which, if used, will increase the probability of detecting a compromise of the seal. The post-mortem examination should be performed as soon as possible after removal of the seal and must be used if the maximum degree of confidence is required. Where post-mortem examination is required, it is assumed that a sample seal from the same lot of seals is available for comparison and that dissection of the seal will be performed to the level necessary for examination of its internal parts.

## CRIMP/WIRE

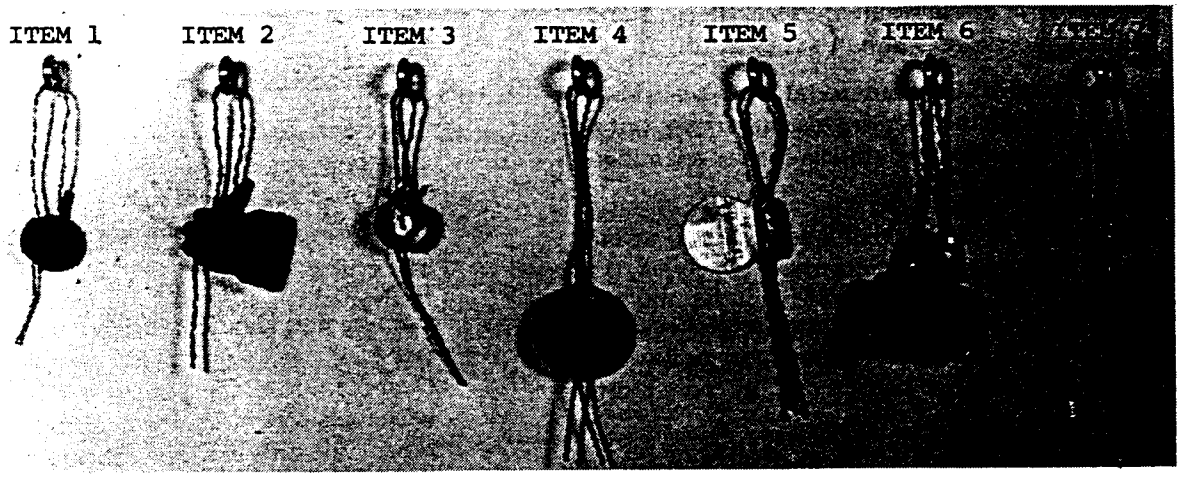


Figure 3

## Description

### Lead/Wire Seals

The lead/wire seals (Items 1 and 2) are small, molded lead cylinders which contain holes through which a wire is passed. Item 2 can be procured with sequential serial numbers on a flag. These seals are installed by means of a seal press that contains dies which provide numbers, letters, or other details embossed on the lead and compresses the lead around the wire.

### Lead Metal Back Seal

The lead metal back seal (Item 3) is basically the same as the lead/wire seal but, in addition, has a copper metal cap stamped with the user's monogram. There is no indication that this seal can be procured with sequential serial numbers.

### Steel Disk Seal

The steel disk seal (Item 4) consists of a steel cup, available in three different sizes, and accompanying paper disk inserts which contain printed information. The seal is attached to the wire using a special die which rolls the outer edge into a bead capturing the paper insert and the wire. This seal can be procured with sequential serial numbers.

### Aluminum Roll-Over Seal

The aluminum roll-over seal (Item 5) is an aluminum stamping similar to a fold/wire seal (see Figure 4) except that the attachment of the wire to the seal is performed by means of a special tool which wraps the aluminum around the wire. These seals cannot be procured with sequential serial numbers.

### Aluminum Crimp Seal

The aluminum crimp seal (Item 6) is an aluminum stamping which is rectangular in shape and contains wire receptacles similar to solderless connectors. The seal is applied by means of a seal press or solderless connector crimping tool. This seal can be supplied with a company identification and sequential serial numbers.

### Aluminum Sleeve Seal

The aluminum sleeve seal (Item 7) is a double-holed aluminum sleeve which may be applied in the same way that the lead/wire seal is applied. This seal has the same features as the lead/wire seal except that it cannot be procured with sequential serial numbers.

## Tamper-Resistance Summary

Compromise of the lead/wire seals (Items 1 and 2) will take more than 5 minutes to perform.

Compromise of the lead metal back seal (Item 3) will take more than 5 minutes to perform but will most likely be detected during careful examination of the installed seal.

Compromise of the steel disk seal (Item 4) will take more than 5 minutes to perform.

Compromise of the aluminum roll-over seal (Item 5) will take more than 2 minutes to perform and most likely will not be detected by post-mortem examination.

Compromise of the aluminum crimp seal (Item 6) will take more than 30 seconds to perform and most likely will not be detected by post-mortem examination.

Compromise of the aluminum sleeve (Item 7) will take more than 5 minutes to perform but will most likely be detected during careful examination of the installed seal.

## Special Installation Guidelines

In the installation of all of these crimp/wire seals, the length of the wire loop should be minimized, making the seal a tight fit around the item being sealed. The loose ends of the wire should be passed through the seal as many times as possible before crimping. Spirally wound wire is recommended to ensure nonslip sealing.

## Verification Inspection

Once the seal is in place, there should be no free play between the seal body and the wire, and the serial number should be verified. The interface between the seal and the wire should be examined carefully for the presence of epoxy or adhesives used to hold the wire to the seal. Post-mortem examination should consist of a comparison of the removed seal with a lot sample and a careful examination of the seal for evidence of crimping with tools other than the designated crimping tool. Since the only unique fingerprint available on these commonly used seals consists of the marks made by the crimping dies or tools, it is important to carefully examine the impressions of the crimped joint. It must be realized that crimping dies are easy to duplicate; therefore, most of these seals are relatively easy to counterfeit.

# FOLD/WIRE

## Description

The fold/wire seal is a sheet-metal stamping designed to fold together and securely hold a wire. The fold lines of the seal are scored so that unfolding will cause the seal to break along the fold lines. Two different types of this seal are available, the single-fold seal (Items 1 and 2) and the double-fold seal (Item 3). Both of these seals can be procured with sequential serial numbers.

## Tamper-Resistance Summary

Compromise of all of the fold/wire seals (Items 1, 2, and 3) will take more than 2 minutes to perform.

## Special Installation Guidelines

Spirally wound wire is recommended to ensure nonslip sealing in the installation of the fold/wire seal. The length of the wire loop should be minimized, making the seal a tight fit around the item being sealed. The loose ends of the wire should be passed through the seal body as many times as possible before the seal is snapped shut.

## Verification Inspection

Once the seal is in place, there should be no free play between the seal body and the wire, and the serial number should be verified. Post-mortem examination should compare the removed seal with a sample seal. Careful examination of the parts after unfolding should reveal no evidence of tampering, such as scratches on the internal and external surfaces. The side flaps adjacent to the wire should be carefully examined for deformation and for scratches which differ from those on the sample.

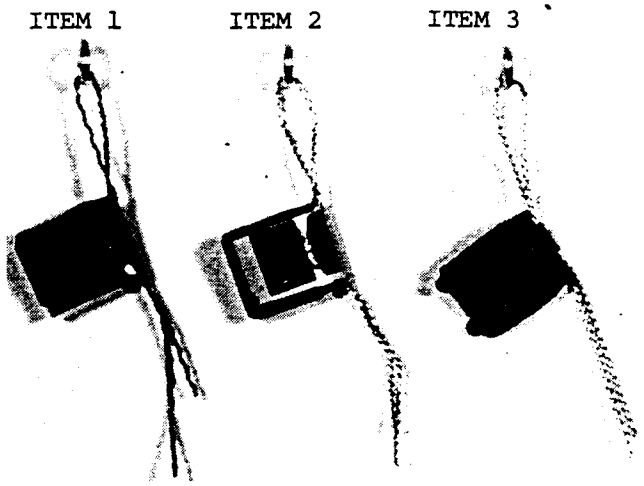


**Figure 4**

# CUP/WIRE

## Description

The cup/wire seal is commonly referred to as a "Type E" seal. It consists of three sheet-metal stampings, two of which are fastened together to form the bottom of the seal, which is comprised of the shell and crown. The third stamping forms a solid top piece. The seal is installed by threading wire through the item to be sealed and then through the holes in the seal bottom and fastening the two wire ends together with a crimp-type sleeve or other device. The top is snapped into the bottom, thereby capturing the wire juncture within the metal cup enclosure.

The cup/wire seal may be ordered in three different sizes; however, only the medium-size (¾-inch-diameter) seal has been tested and evaluated. All tests were performed on seals which were constructed with brass bottoms and copper tops, even though the seal can be ordered with steel parts. Fingerprinting techniques and verification procedures were developed by Brookhaven National Laboratory for this seal.

## Tamper-Resistance Summary

Compromise of the cup/wire seal, whether it is fingerprinted or not, will take more than 10 minutes to perform and will require the use of special tools as well as substitution of the wire and sleeve.

## Special Installation Guidelines

To minimize accidental breakage, stainless-steel wire with a minimum of 15 strands is desirable. A metal sleeve may be used to crimp the wire ends together within the cup. Both the top and bottom of the seal should be imprinted with a serial number. The length of the wire loop should be minimized, making the seal a tight fit around the item being sealed, which may prevent the insertion of special tools. Fingerprinting of the seals, which is performed according to the procedures outlined in Reference 3, is optional.

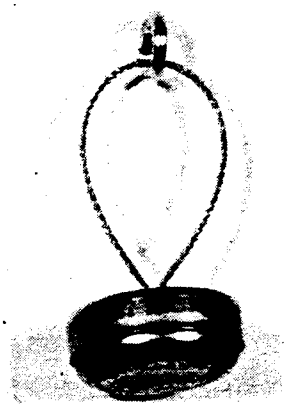

**Figure 5**

## Verification Inspection

Once the seal is in place, the serial number on the seal should be verified and inspection for physical damage or signs of tampering should be performed. Post-mortem examination should compare the removed seal with a lot sample, and the top serial numbers should be compared with the bottom serial numbers. If fingerprinting has been used, the fingerprint must be verified after the seal has been cut open. The metal sleeve which is used to hold the ends of the wire together should be compared with the lot samples. The surface areas of the shell, crown, and top should be examined for abrasions. The shape of the parts should be carefully compared with the sample parts to determine if dies other than the production dies were used to form the seal parts, particularly the bottom section of the seal.

# WIRE HASP PADLOCK

## Description

The plastic/wire padlock seals (Items 1, 2, and 4) consist of a plastic body with a solid steel-wire shackle. This type of seal becomes operational when the shackle is pushed into the plastic body. Attempts to withdraw the shackle cause the ends of the wire to become embedded in the plastic. The steel/wire padlock (Item 3) uses the same principle as the plastic/wire padlock except that the wire ends become trapped in the body due to the configuration of the steel stamping. All these seals can be procured with sequential serial numbers.

## Tamper-Resistance Summary

Compromise of all the plastic/wire padlocks (Items 1, 2, and 4) will take more than 15 seconds to perform and most likely will not be detected by post-mortem examination. Compromise of the steel/wire padlock (Item 3) will take more than 5 minutes to perform and will require a greater effort than does compromise of the plastic/wire padlocks.

## Special Installation Guidelines

During installation of the wire hasp padlocks, the seal body should be pulled to ensure that the wire is firmly embedded within the body. The plastic seals will support combustion.

## Verification Inspection

Once the plastic/wire padlock is in place, there should be a minimum amount of free play between the wire and the plastic body. When the steel/wire padlock is in place, there should be about ¼ inch

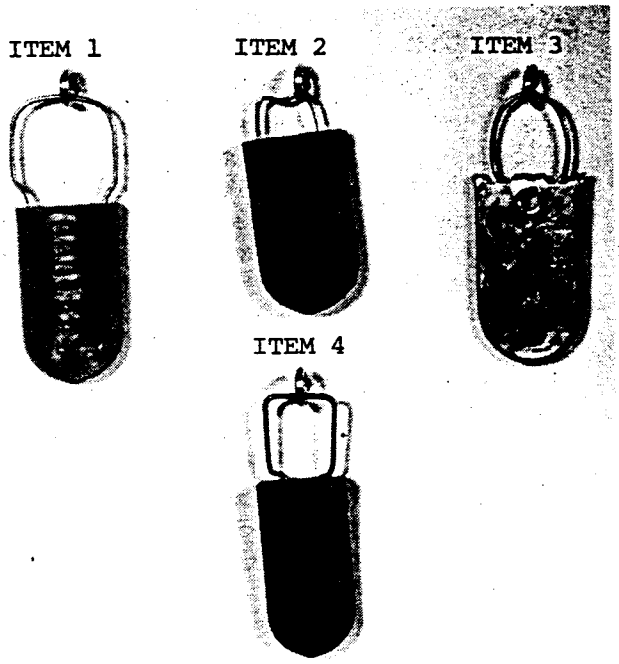


**Figure 6**

of free play between the steel body and the wire, and the serial number should be verified. Post-mortem examination should compare the removed seal with a sample seal. Careful examination of the parts should be made to ensure that there are no signs of forcible entry. The wire shackle should be carefully examined for abrasions which do not appear on the sample.

Post-mortem examination of Items 1, 2, and 4 may not provide conclusive evidence of tampering.

# PLASTIC PADLOCK

## Description

The plastic padlock seals ( Items 1 through 5) are constructed of a one-piece plastic molded part which uses various locking mechanisms to secure the shackle in place. All of the padlock seals are self-locking. The materials generally used are polypropylene, polyethylene, and nylon. All the seals, except Item 5, can be procured with sequential serial numbers.

## Tamper-Resistance Summary

Compromise of Item 1 will take more than 30 seconds to perform. Compromise of the other seals (Items 2, 3, 4, and 5) will take more than 2 minutes to perform but will most likely be detected during careful examination of the installed seal.

## Special Installation Guidelines

During installation of the plastic padlock seals, the locking mechanism should be engaged and the seal body should be pulled to verify that it is locked. The plastic used in these padlock seals will support combustion.

## Verification Inspection

The serial number should be verified. Once the seal is in place, the shackle must have free play in the body; the shackle should be smooth-textured without signs of heat welding. Post-mortem examination should compare the removed seal with a sample seal, and careful examination should reveal no signs of heat welding. All parts of the latching mechanism must be present, and the shackle should break before the latching mechanism fails.

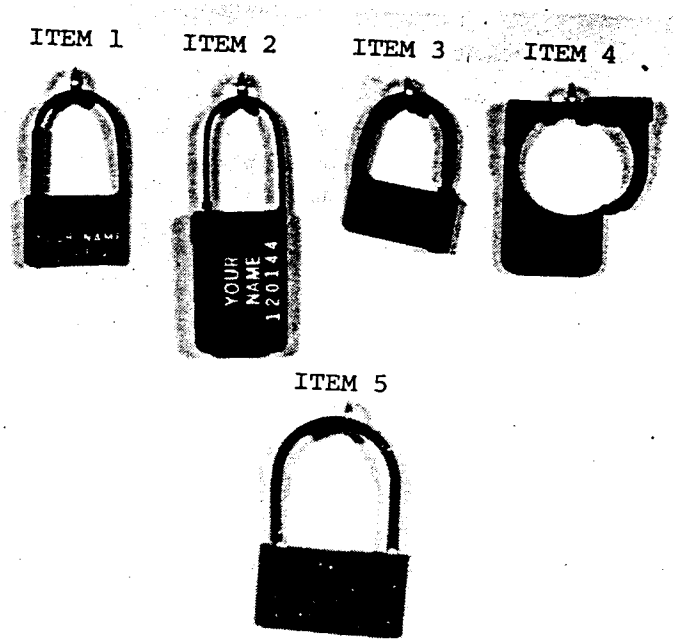


**Figure 7**

# PLASTIC TIE

## Description

The plastic tie seals (Items 1 and 2) are constructed of a one-piece, plastic molded part and are available in two types. Both types consist of a serrated plastic string which may be pulled through the hole of the seal body, which contains spring fingers. The fingers grasp the serrated string and prevent its removal. Item 1 can be procured with sequential serial numbers, while Item 2 cannot.

## Tamper-Resistance Summary

Compromise of the plastic tie seals will take more than 1 minute to perform.

## Special Installation Guidelines

When plastic seals are used, the length of the closed loop should be minimized, making the seal a tight fit around the item being sealed. The free length of the serrated string should not be removed. The plastic used in these seals will support combustion.

## Verification Inspection

Once the seal is in place, the serial number should be verified; the free length of the serrated string must be present. The serrated string should have free play in the seal body and should not pull loose from the body before it breaks, either when in place or during post-mortem examination. Post-mortem examination should compare the removed seal with a sample seal, and careful examination should show no signs of heat welding.

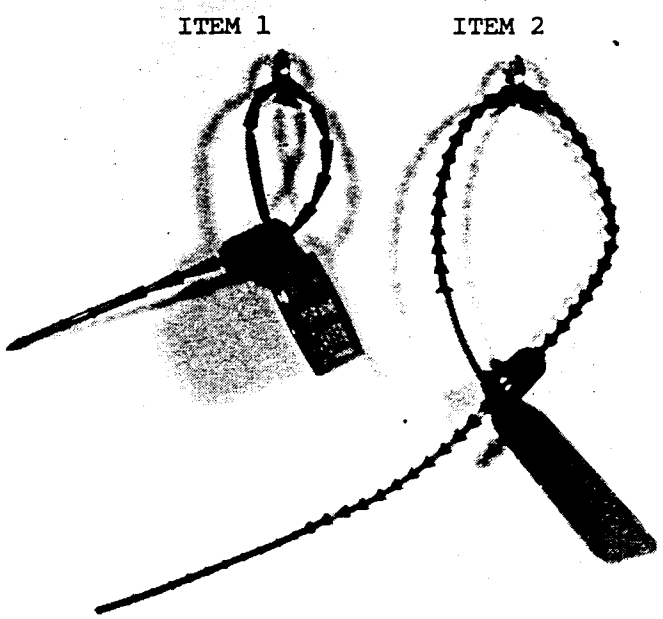


Figure 8

# CAR/BOX END

## Description

The car/box end seals (Items 1 through 3) are steel-strap seals, the latching mechanism of which is contained within a folded box located on one end of the strap. All of these seals can be procured with the company name or logo and sequential serial numbers stamped in the strap.

## Tamper-Resistance Summary

Compromise of the car/box end seals (Items 1, 2, and 3) will take more than 30 seconds to perform and most likely will not be detected by post-mortem examination.

## Special Installation Guidelines

The car/box end seal should be installed according to the manufacturer's instructions.

## Verification Inspection

Once the car/box end seal is in place, the serial number and any other identifying characteristics should be verified and a check should be made to ensure that there is the proper amount of end play in the latching mechanism. There should be about ⅛-inch but not as much as ⅜-inch free play. Post-mortem examination should compare the removed seal with a sample seal and careful inspection should be performed to detect tampering. The seal latching surfaces should be examined for evidence of abrasions which do not appear on the sample seal.

Post-mortem examination may not provide conclusive evidence of tampering.

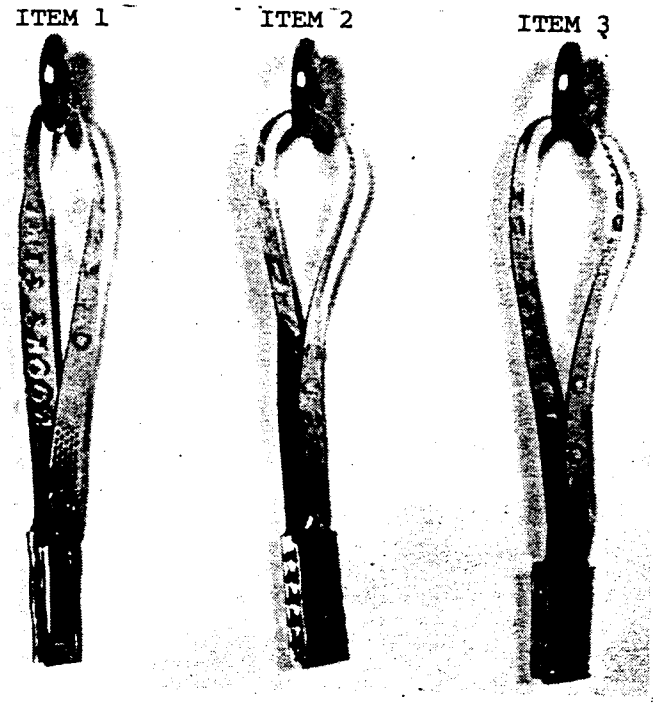


Figure 9

# CAR/PLASTIC

## Description

The car/plastic seals are plastic-strap seals manufactured as single- or double-piece plastic molded parts. The seal latching mechanism is contained in a cylinder at one end of the strap. Items 1 and 3 have spring fingers in the seal body which grasp the cylindrical end of the strap. In Item 2, the spring fingers are located on the end of the strap. All of these seals can be procured with the company name or logo and sequential serial numbers stamped on the strap.

## Tamper-Resistance Summary

Compromise of Items 1 and 3 will take more than 3 minutes to perform but will most likely be detected during careful examination of the installed seal. Compromise of Item 2 will take more than 15 seconds to perform.

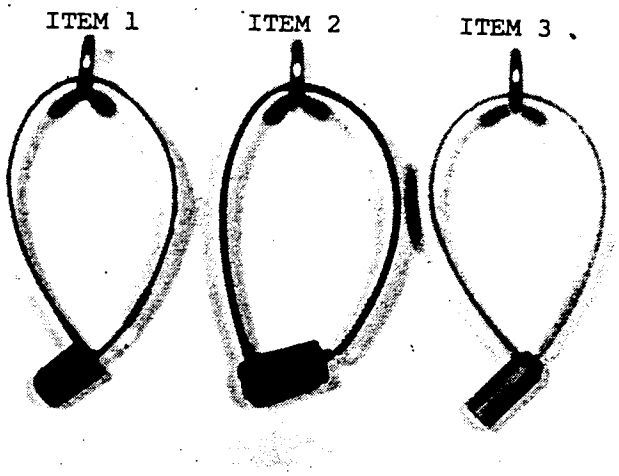


**Figure 10**

## Special Installation Guidelines

The car/plastic seal should be installed according to the manufacturer's instructions. The plastic used in these seals will support combustion.

## Verification Inspection

Once the seal is in place, the serial number and any other identifying characteristics should be verified. A check should be made to ensure that the strap has free rotation in the body and the proper amount of end play. The strap should be inspected for a smooth texture and should be twisted to test the shear strength. Post-mortem examination should compare the external surface of the removed seal with a sample seal. The strap should break before it can be pulled out of the seal body. The body should be opened and the internal parts inspected and carefully compared with the sample. The strap should be examined for evidence of heat welding.

# CAR/BALL END

## Description

The car/ball end seals are steel-strap seals, the latching mechanism of which is contained within a crimped ball located on one end of the strap. The latching mechanism is a piano-wire loop which captures both ends of the strap. Item 1 has one wire loop, while Item 2 has two loops. All of these seals can be procured with the company name or logo and sequential serial numbers stamped in the strap.

## Tamper-Resistance Summary

Compromise of the car/ball end seal will take more than 5 minutes to perform and will require the use of special tools.

## Special Installation Guidelines

The car/ball end seal should be installed according to the manufacturer's instructions.

## Verification Inspection

Once the seal is in place, the serial number and any other identifying characteristics should be verified. A check should be made to ensure that there is a proper amount of end play in the latching mechanism. Post-mortem examination should compare the removed seal with a sample seal, and careful inspection of the exterior and interior surfaces should be performed to determine if dies other than production dies were used to form the ball enclosure. The ball housing should be opened to verify that all the internal parts are present.


**Figure 11**

# CABLE

## Description

Cable seals are high-strength security seals which use 3/16-inch or 1/4-inch aircraft cable. The seals are self-locking and employ locking mechanisms which consist of roller-incline, ball-incline, and locking rings contained within steel bodies. All of the seals can be procured with the company names and sequential serial number identification.

## Tamper-Resistance Summary

Compromise of Item 1 will take more than 30 seconds to perform and most likely will not be detected by post-mortem examination. Compromise of Item 2 will take more than 10 minutes to perform. Compromise of Item 3 will take more than 2 minutes to perform. Compromise of Item 4 will take more than 30 seconds to perform.

## Special Installation Guidelines

Items 1 and 2 should be installed so that the length of the cable threaded through the hasp is minimized, making a tight fit on the object being sealed. Items 2 and 4 should have serial numbers applied to both parts of the seal.

## Verification Inspection

Once the seal is in place, the serial numbers and any other identification markings should be verified. Post-mortem examination should compare the removed seal with a sample seal and careful inspection of the exterior and interior surfaces

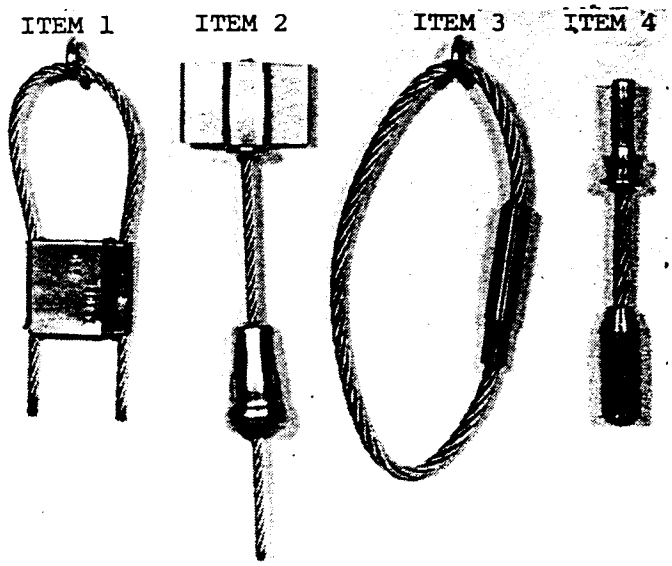


**Figure 12**

should be performed to detect tampering. The body of the Item 2 seal should be examined for a small hole drilled in the end. Tensile test data for Item 3 seals which have not been tampered with should be obtained and all removed seals should be subjected to the same tensile test. A significant drop in tensile strength is a good indicator of seal compromise. The body of the Item 4 seal should be examined internally and carefully compared with the sample for unusual signs of abrasion. The cable end of the seal should also be similarly examined.

# BOLT

## Description

The bolt seals are based on two different design principles. Item 1 is an unthreaded pin which is inserted into a cylinder which contains a C-ring as the locking mechanism. Item 2 is simply a threaded bolt which is inserted into a specially designed spin nut. The spin nut will move up and down the bolt, provided that the threads are smooth, but will not advance when the threads are burred or when resistance is encountered. Item 2 may also be supplied with a regular nut in place of the spin nut. These seals can be procured with sequential serial numbers.

## Tamper-Resistance Summary

Compromise of Item 1 will take more than 30 seconds to perform. Compromise of Item 2 equipped with the regular nut will take more than 5 minutes to perform, while compromise of Item 2 equipped with the spin nut will take more than 10 minutes to perform.

## Special Installation Guidelines

The Item 1 bolt should be installed according to the manufacturer's instructions and both parts should contain serial numbers. Item 2 should be installed so that the nut or spin nut is threaded tightly against the hasp and the threads are damaged beyond repair.

## Verification Inspection

Once the seal is in place, the serial numbers and any other identification markings should be verified.

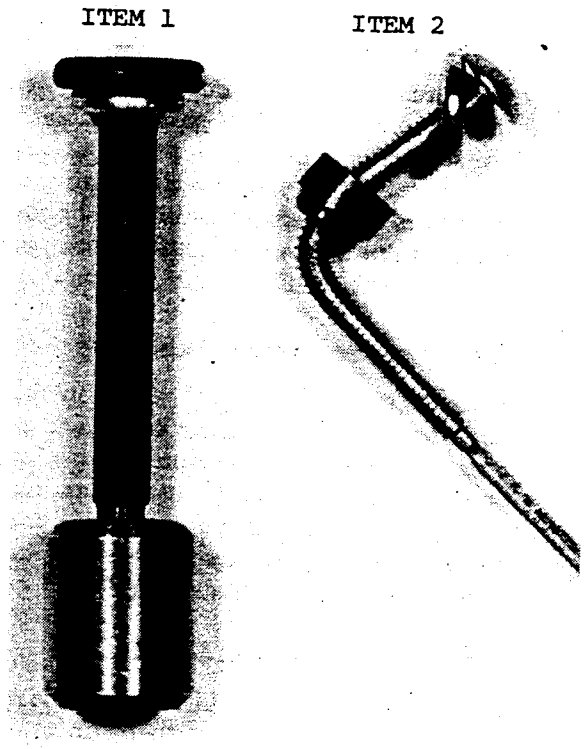


**Figure 13**

Post-mortem examination should compare the removed seal with a sample seal. The internal parts of Item 1 should not reveal signs of abrasion. The head of the Item 2 bolt should be examined to verify that it has not been removed and replaced.

# LOCK

## Description

Lock seals are keyless locks. The body of this seal contains the locking mechanism, and a hardened shackle is utilized. The locking mechanism for Item 1 comprises rings with round cross sections. The locking mechanism for Item 2 consists of spring-loaded pins which engage the shackle. Both seals can be procured with consecutive serial numbers stamped on the housing.

## Tamper-Resistance Summary

Compromise of Item 1 will take more than 2 minutes to perform. Compromise of Item 2 will require more than 60 minutes to perform and will require substitution of parts.

## Special Installation Guidelines

Serial numbers should be applied to both the shackle and body of the lock seals. The seals should be installed according to the manufacturer's instructions.

## Verification Inspection

Once the seal is in place, the serial number should be verified. Post-mortem examination should compare the removed seal with a sample seal. The external seal surfaces should be free of any marks which might indicate forcible entry or tampering. The shackle and internal parts of the Item 1 seal body should be compared with the sample seal and examined for indications of forcible entry. The Item 2 seal should be examined for evidence of part replacement and repainting.

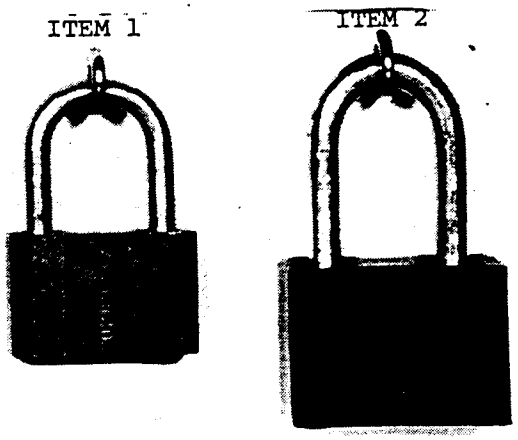


Figure 14

# STRAP

## Description

Strap seals are sheet-metal seals which are used for steel strapping. These seals have a distinctive lithographed design. The lithograph plates are controlled by the Department of Energy, Albuquerque Operations Office (DOE/ALO). Three sizes of seals are available: ⅜-inch, ⅝-inch, and 1¼-inch. The distribution of the seals is controlled by DOE/ALO. The seals are used in conjunction with standard steel strapping for boxes, crates, and other rectangular packages. The ⅜-inch seal and strapping may also be used in conjunction with special brackets to seal drums. The seals cannot be procured with sequential serial numbers.

## Tamper-Resistance Summary

Compromise of the strap seal will take more than 5 minutes to perform and will require the use of special tools and new strap material.

## Special Installation Guidelines

Serial numbers should be applied to the seals. The use of regular strapping tools is recommended.

## Verificaton Inspection

Once the seal is in place, the serial number should be verified and the tightness of the strap should be checked. Post-mortem examination should compare the removed seal with a sample seal. The crimping tool marks should also be compared. The seal should be examined for excessive fracturing of the metal in the crimp area.

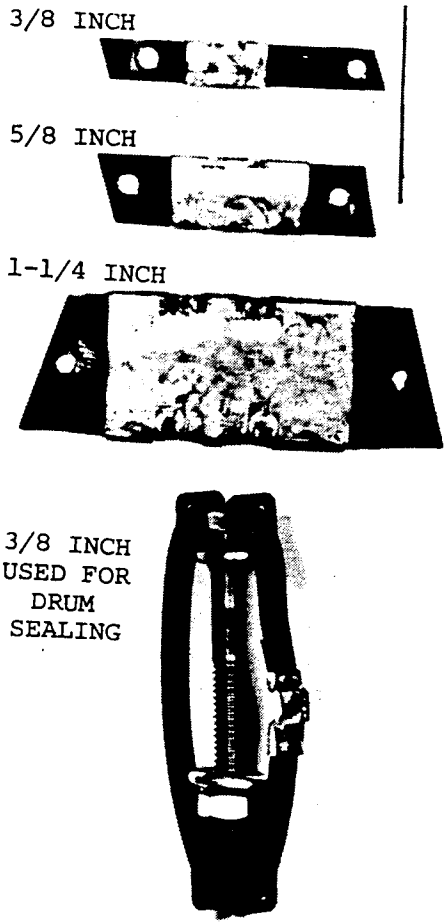


**Figure 15**

# LABEL

## Description

Label seals are constructed of sheet vinyl or paper with pressure-sensitive backing. The seal material will tear if attempts are made to peel it. Attempts to remove the seal by means of solvents will cause the background ink to run or will destroy the seal material. These seals may also be used as a label to provide information on the container's contents. Reference 2 provides guidelines for the selection and use of pressure-sensitive seals on containers used to store special nuclear materials. Label seals can be procured with consecutive serial numbers which take the form of either printed or perforated dots on the label.

The label seals evaluated in this section meet the requirements identified in Reference 2. Purchase specifications must be prepared by the users of these seals to meet their specific requirements. The only known sources for manufacturing labels which meet Reference 2 requirements are the companies listed under label seals in Table I.

## Tamper-Resistance Summary

According to all tests and evaluations performed to date, label seals are not readily susceptible to compromise methods.

## Special Installation Guidelines

The label seal should be installed as specified in Reference 2, which requires that there be at least a 1-inch overlap on either side of the container parting line and that the surface to which the seal is applied be smooth and clean.

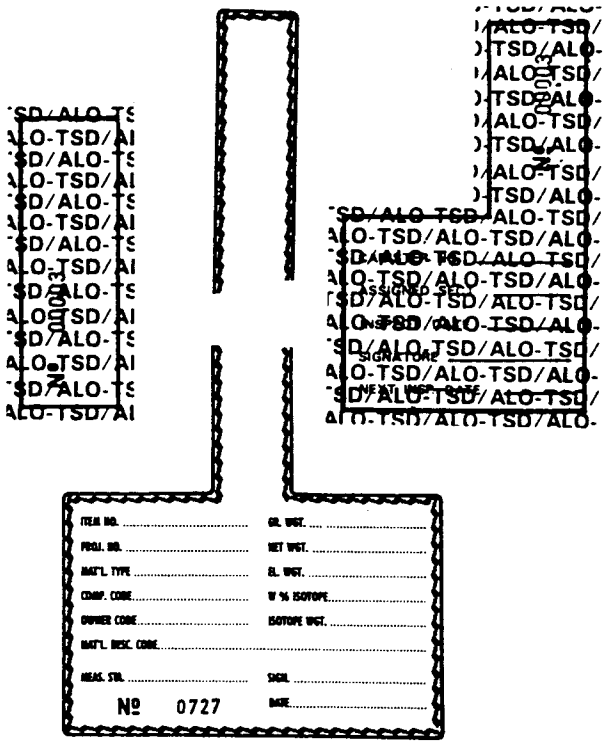


Figure 16

## Verification Inspection

Prior to the breaking or voiding of a label seal which is in place, the seal should be inspected by authorized personnel to verify that the seal is not broken, damaged, or improperly applied and that the serial number is correct. A sample seal should be compared to the applied seal prior to its removal.

# 4. NEW SEAL DEVELOPMENTS

Section 4 presents an overview of all known seal developments. The first seals discussed have been developed through the prototype stage, while the second group of seals consists of conceptual designs. The status of each specific seal's development is presented. However, it should not be inferred from this presentation that all these seals will be developed for production.

New seal development represents an attempt to obtain an improved security seal through the use of physical principles not found in commercially available seals. Unique fingerprint and field verification tests are included in the design goal for most of these seals. These improvements are designed to increase the probability of tamper detection and to eliminate some of the limitations of the sealing systems presented in Section 1.

## ELECTRONIC SEAL

An electronic sealing system was developed by Sandia Laboratories for the IAEA. This system has been developed through the prototype stage and 10 units have been provided to the IAEA for evaluation.

The sealing system consists of an electronic seal with a computer programmer-verifier unit. The seal is made up of a fiber optic bundle formed into a loop, both ends of which are captured in the electronic housing. This housing contains a power supply, a display generator, and a tamper-responding container. The fiber optics are used to establish loop integrity. Each seal is programmed to display unique sequences of numbers and letters through a single-digit, liquid-crystal display contained in the housing.

The computer programmer-verifier unit is used to program each seal prior to installation. Once in place, any electronic seal may be verified both on site and remotely by a comparison of its digital display output with the reference output provided by the computer programmer-verifier.

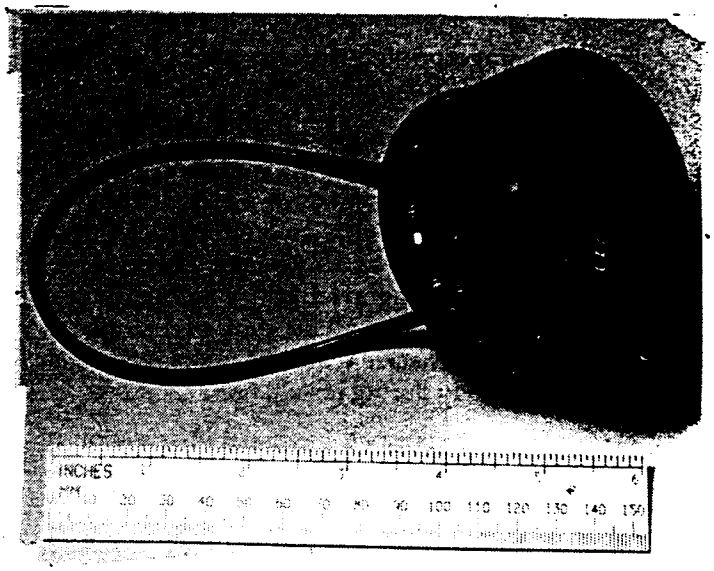


**Figure 19**

The seal is reusable and will allow one authorized opening and closing before replacement or reprogramming is required. The seal is designed for an operating life of 6 months without servicing.

## TAMPER-INDICATING REUSABLE SEAL

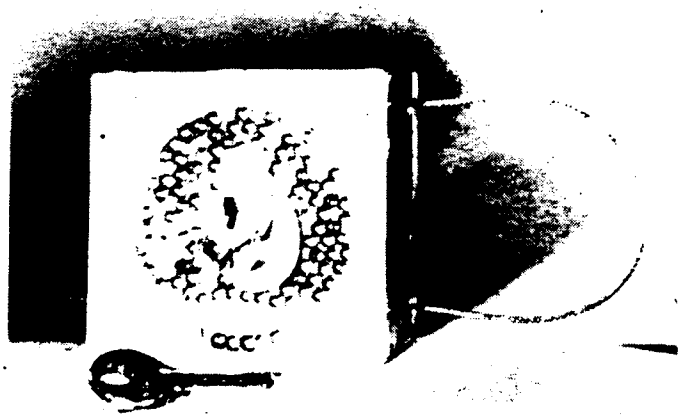

**Figure 20**

The tamper-indicating reusable seal is being developed by Argonne National Laboratory to meet a specific seal problem encountered within their facility. Prototype models have been fabricated and a patent disclosure for this seal has been issued.

This seal is constructed with a wire or round barstock shackle. The body of the seal contains a key-operated rotating drum with colored balls. The balls are scrambled each time the shackle is opened and closed. This generates a random orientation of the balls; consequently, a new code is obtained each time the seal is applied. The colored ball code is contained in a pocket outside the rotating drum but still within the seal housing.

Verification of seal integrity is performed by means of visual observation of the color code and by a comparison of the serial number with recorded reference data.

## PLASTIC FLECK SEAL

Brookhaven National Laboratory has developed a plastic fleck seal for possible use as a field-readable, fingerprinted security seal. Prototype seals of this type have been constructed.

The seal consists of a multistrand wire shackle with plastic plugs molded onto each end of the wire. The body of the seal consists of a cylinder of clear thermosetting resin with colored particles suspended within the plastic. The periphery of the body contains an engraved grid which permits a coordinate reading of all or part of the plastic flecks. The wire shackle would be glued in place in the cylinder body during installation.

Verification is performed by visual observation of the plastic fleck coordinate locations and by comparison of these coordinates with recorded reference data.

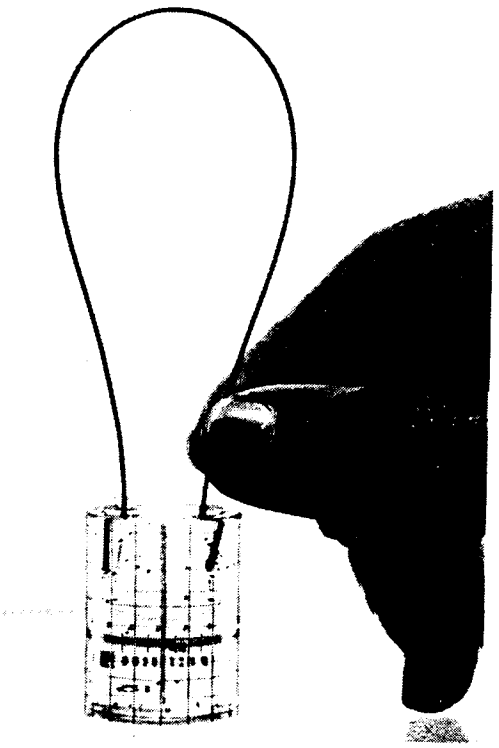

Figure 21

## STRESSED-GLASS SEAL

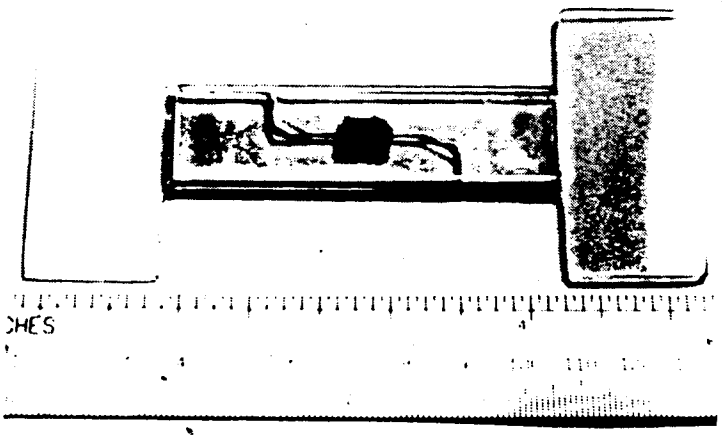

Figure 22

A stressed-glass seal was developed by Sandia Laboratories and prototypes of this seal have been fabricated.

The prototype seal design is dumbbell-shaped and consists of two stressed-glass keys which are inserted into a stressed-glass sheath from its opposite ends and then locked together with an S-shaped metal spring. A pulling force exerted on either key or any penetration of the stressed-glass surfaces will cause the glass to shatter.

Verification of the seal may be accomplished by the use of polarized light to compare stress patterns plus any other identification etched in the glass against a reference photograph.

## ULTRASONIC SEAL

The development of seals based on ultrasonic technology has been under development at the EURATOM Joint Research Centre at Ispra, Italy, for several years. This seal development has included general purpose seals as well as special seals for spent fuel assemblies. Sandia Laboratories is also developing ultrasonic seals for spent fuel based on the technology that was originally developed by EURATOM.

The light water reactor (LWR) seal design consists of a disk or cylinder which is attached to the fuel bundle. The seal houses a random matrix slug of mixed density materials whose density pattern can be scanned by a piezoelectric ultrasonic crystal monitor positioned on the seal's surface. The scan pattern data are digitized and converted to a number which is then compared with the reference data (number) for each seal.

The scanning device is designed to operate underwater in the environment found at a spent fuel storage pool (SFSP).

Other safeguards applications for ultrasonic seals which are being pursued include an ultrasonic scan of the entire SFSP and uranium hexaflouride ($UF_6$) cylinders.

## FIBER OPTIC SEAL

### Atlantic Research Corporation

This fiber optic sealing system, known as the Linear Array Seal System (LASS), is being developed by Atlantic Research Corporation under contract to the United States Arms Control and Disarmament Agency (USACDA). Development is in the preprototype stage.

As proposed, the sealing system would consist of a Fiber Optic Linear Array (FOLA) seal plus an electronic interrogator. The FOLA seal is made up of a fiber optic bundle formed into a loop, both ends of which are captured in a split housing. The intersection of the fibers within the body occurs at right angles with the fibers interwoven at random.

An electronic interrogator scans both the input and output ends of the fiber arrays and provides information to the operator on whether tampering has occurred. Tampering is detected by instrument comparison of the present data with reference data for the same serial-numbered seal.

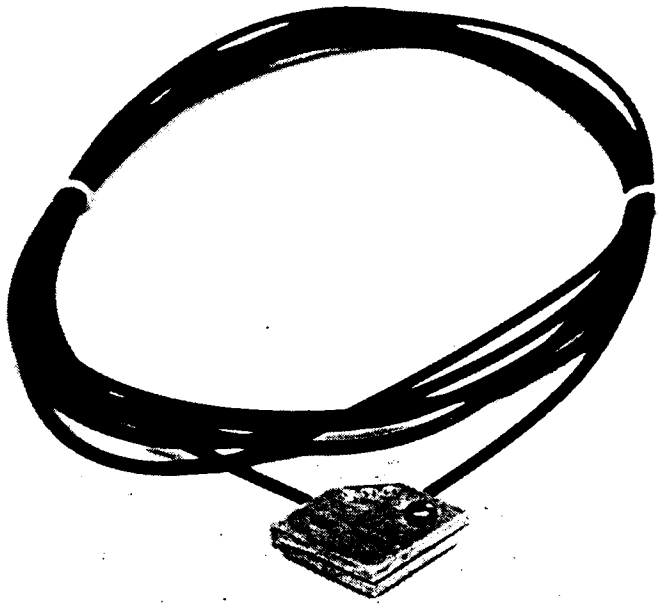

Figure 23

## PLASTIC RANDOM WIRE SEAL

A conceptual design for this seal has been developed by Professor McCormick, College of Engineering, Department of Nuclear Engineering, University of Washington.

This seal, if developed, would consist of a 49-strand wire, the frayed ends of which are embedded in clear plastic. Both wire ends are rectangular in shape; however, one wire end contains a depression into which the other end is closely fitted. This second end also contains a paper onto which a computer-generated, random-numbered grid is printed; the frayed ends of the wire lie on top of the grid. Seal installation would consist of bonding the two plastic parts together.

Seal integrity would be verified through the use of a magnifying glass to determine the location of the wire ends on the grid and a comparison of these data with reference data for the examined seal.

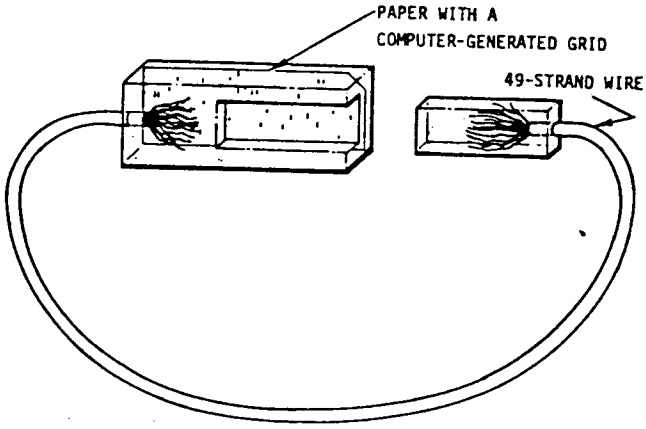


Figure 24

## PHOTO-REFLECTIVE PARTICLES FOR SECURE LABELS

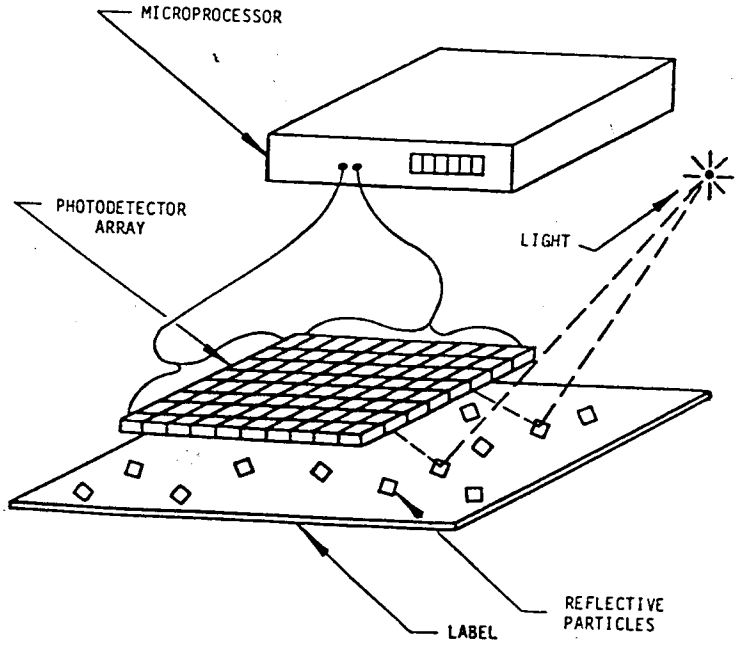


Figure 25

Sandia Laboratories has developed a label seal concept that uses small reflective particles applied randomly to a surface or embedded in a material to create a label. The particles may be crystalline materials, metal flakes, aluminized plastics, or any materials that reflect light over a small range of angles. When the label is illuminated by a point light source, only a few of the particles will reflect the light to the observer. Changing the position of the light and/or the observer will cause a different set of particles to reflect to the observer. The pattern, therefore, is three-dimensional in that its significant features must be described not only by the orthogonal coordinates of each reflective particle but also by its angles with respect to the orthogonal plane.

The adversary would not know what observer or light source locations are being used or what area

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